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METHOD AND APPARATUS FOR ESTIMATION OF COMPONENT GATING AND SHORTAGE RISK IN MANUFACTURING OPERATIONS

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CROSS-REFERENCE TO RELATED APPLICATIONS

5 This invention claims priority from a provisional application entitled "METHOD AND BUSINESS PROCESS FOR ESTIMATION OF COMPONENT GATING AND SHORTAGE RISKS IN ASSEMBLE-TO-ORDER MANUFACTURING OPERATIONS" (U.S. Provisional Application Number 60/229,840), filed August 31, 2000, having Balazs Kralik, Michael Goldbach, and

10 Paul Dagum as inventors, and having as assignee Rapt, Inc., the assignee of the present invention. The aforementioned provisional patent application is incorporated herein by reference, in its entirety and for all purposes.

BACKGROUND OF THE INVENTION

Field of the Invention

15 This invention relates generally to manufacturing resource allocation, and more particularly, to risk management in the procurement of unfinished goods by estimation of component gating and shortage risk.

Description of the Related Art

An assemble-to-order (ATO) manufacturing process is one in which products are manufactured from raw components only as orders are received. While ATO processes are more efficient than manufacture-to-stock (MTS) operations, in which products are produced before demand is known, they are not without significant risks. If component availability is below what is required to meet product demand, then fulfillment of orders is either delayed or fails. Conversely, if excess component inventory remains after demand is met, the excess is either returned to the supplier,

usually at a loss, or held until future need. Thus any component inventory that does not exactly meet demand incurs some financial loss for the manufacturer. Being able to predict the risk of component shortage for each component allows a manufacturer to make more informed business decisions.

5 **SUMMARY OF THE INVENTION**

In one embodiment, a method for estimation of component gating risk in manufacturing operations is disclosed. The method includes generating an altered component plan by altering a component plan for a component, computing a mean production value using the altered component plan, and computing the component gating risk using the mean production value.

In another embodiment, a method for estimation of component gating risk in manufacturing operations is disclosed. The method includes generating an increased component plan by increasing a component plan for a component, computing a first mean production value using the increased component plan, generating a decreased component plan by decreasing the component plan for the component, computing a second mean production value using the decreased component plan, and computing the component gating risk using the first and the second mean production values.

In still another embodiment, a method for estimation of component shortage risk in manufacturing operations is disclosed. The method includes identifying a component and computing r . In this embodiment, r is the component shortage risk, and is defined by

$$r = \int_d^{\infty} N(x, \mu, \sigma^2) dx$$

where d is a maximum expeditable level of the component, $N(x, \mu, \sigma^2)$ is a normal density function having a mean equal to μ and a variance equal to σ^2 , a is a vector of connect rates for the component, μ is a mean demand, and Σ represents demand covariance.

The foregoing is a summary and thus contains, by necessity, simplifications, generalizations and omissions of detail; consequently, those skilled in the art will appreciate that the summary is illustrative only and is not intended to be in any way limiting. As will also be apparent to one of skill in the art, the operations disclosed 5 herein may be implemented in a number of ways, and such changes and modifications may be made without departing from this invention and its broader aspects. Other aspects, inventive features, and advantages of the present invention, as defined solely by the claims, will become apparent in the non-limiting detailed description set forth below.

10 **BRIEF DESCRIPTION OF THE DRAWINGS**

The present invention may be better understood, and its numerous objects, features, and advantages made apparent to those skilled in the art by referencing the accompanying drawings.

15 Fig. 1 is a block diagram illustrating a network environment in which commercial transaction processing according to embodiments of the present invention may be practiced.

Fig. 2 is a block diagram illustrating a computer system suitable for implementing embodiments of the present invention.

20 Fig. 3 is a block diagram illustrating the interconnection of the computer system of Fig. 2 to client and host systems.

The use of the same reference symbols in different drawings indicates similar or identical items.

DETAILED DESCRIPTION OF THE INVENTION

25 The following is intended to provide a detailed description of an example of the invention and should not be taken to be limiting of the invention itself. Rather, any number of variations may fall within the scope of the invention which is defined in the claims following the description.

Introduction

The present invention addresses this need by providing a novel method for estimating component shortage risk and component gating risk. A gating component is one that is the most short and therefore determines the allowable level of

5 production. Gating risk for a particular component is the risk that the component will be the gating component. Estimation of component shortage and gating risks is particularly complicated when a large number of products are made from a large number of the same components, and thus the present invention is particularly advantageous under such conditions.

10 An Example Computing and Network Environment

Fig. 1 is a block diagram illustrating a network environment in which a system according to the present invention may be practiced. As is illustrated in Fig. 1, network 100, such as a private wide area network (WAN) or the Internet, includes a number of networked servers 110(1)-(N) that are accessible by client computers

15 120(1)-(N). Communication between client computers 120(1)-(N) and servers 110(1)-(N) typically occurs over a publicly accessible network, such as a public switched telephone network (PSTN), a DSL connection, a cable modem connection or large bandwidth trunks (e.g., communications channels providing T1 or OC3 service). Client computers 120(1)-(N) access servers 110(1)-(N) through, for example, a service provider. This might be, for example, an Internet Service Provider (ISP) such as 20 America On-Line™, Prodigy™, CompuServe™ or the like. Access is typically had by executing application specific software (e.g., network connection software and a browser) on the given one of client computers 120(1)-(N).

One or more of client computers 120(1)-(N) and/or one or more of servers 25 110(1)-(N) may be, for example, a computer system of any appropriate design, in general, including a mainframe, a mini-computer or a personal computer system. Such a computer system typically includes a system unit having a system processor and associated volatile and non-volatile memory, one or more display monitors and keyboards, one or more diskette drives, one or more fixed disk storage devices and 30 one or more printers. These computer systems are typically information handling

systems which are designed to provide computing power to one or more users, either locally or remotely. Such a computer system may also include one or a plurality of I/O devices (i.e., peripheral devices) which are coupled to the system processor and which perform specialized functions. Examples of I/O devices include modems,
5 sound and video devices and specialized communication devices. Mass storage devices such as hard disks, CD-ROM drives and magneto-optical drives may also be provided, either as an integrated or peripheral device. One such example computer system, discussed in terms of client computers 120(1)-(N) is shown in detail in Fig. 2.

It will be noted that the variable identifier "N" is used in several instances in
10 Fig. 1 to more simply designate the final element (e.g., servers 110(1)-(N) and client computers 120(1)-(N)) of a series of related or similar elements (e.g., servers and client computers). The repeated use of such variable identifiers is not meant to imply a correlation between the sizes of such series of elements, although such correlation may exist. The use of such variable identifiers does not require that each series of
15 elements has the same number of elements as another series delimited by the same variable identifier. Rather, in each instance of use, the variable identified by "N" may hold the same or a different value than other instances of the same variable identifier.

Fig. 2 depicts a block diagram of a computer system 210 suitable for implementing the present invention, and example of one or more of client computers 20 120(1)-(N). Computer system 210 includes a bus 212 which interconnects major subsystems of computer system 210 such as a central processor 214, a system memory 216 (typically RAM, but which may also include ROM, flash RAM, or the like), an input/output controller 218, an external audio device such as a speaker system 220 via an audio output interface 222, an external device such as a display screen 224 via
25 display adapter 226, serial ports 228 and 230, a keyboard 232 (interfaced with a keyboard controller 233), a storage interface 234, a floppy disk drive 236 operative to receive a floppy disk 238, and a CD-ROM drive 240 operative to receive a CD-ROM 242. Also included are a mouse 246 (or other point-and-click device, coupled to bus 212 via serial port 228), a modem 247 (coupled to bus 212 via serial port 230) and a
30 network interface 248 (coupled directly to bus 212).

Bus 212 allows data communication between central processor 214 and system memory 216, which may include both read only memory (ROM) or flash memory (neither shown), and random access memory (RAM) (not shown), as previously noted.

The RAM is generally the main memory into which the operating system and application programs are loaded and typically affords at least 16 megabytes of memory space. The ROM or flash memory may contain, among other code, the Basic Input-Output system (BIOS) which controls basic hardware operation such as the interaction with peripheral components. Applications resident with computer system 210 are generally stored on and accessed via a computer readable medium, such as a

hard disk drive (e.g., fixed disk 244), an optical drive (e.g., CD-ROM drive 240), floppy disk unit 236 or other storage medium. Additionally, applications may be in the form of electronic signals modulated in accordance with the application and data communication technology when accessed via network modem 247 or interface 248.

Storage interface 234, as with the other storage interfaces of computer system 210, may connect to a standard computer readable medium for storage and/or retrieval of information, such as a fixed disk drive 244. Fixed disk drive 244 may be a part of computer system 210 or may be separate and accessed through other interface systems. Many other devices can be connected such as a mouse 246 connected to bus 212 via serial port 228, a modem 247 connected to bus 212 via serial port 230 and a

network interface 248 connected directly to bus 212. Modem 247 may provide a direct connection to a remote server via a telephone link or to the Internet via an internet service provider (ISP). Network interface 248 may provide a direct connection to a remote server via a direct network link to the Internet via a POP (point of presence). Network interface 248 may provide such connection using wireless techniques, including digital cellular telephone connection, Cellular Digital Packet Data (CDPD) connection, digital satellite data connection or the like.

Many other devices or subsystems (not shown) may be connected in a similar manner (e.g., bar code readers, document scanners, digital cameras and so on).

Conversely, it is not necessary for all of the devices shown in Fig. 2 to be present to practice the present invention. The devices and subsystems may be interconnected in

different ways from that shown in Fig. 2. The operation of a computer system such as that shown in Fig. 2 is readily known in the art and is not discussed in detail in this application. Code to implement the present invention may be stored in computer-readable storage media such as one or more of system memory 216, fixed disk 244, 5 CD-ROM 242, or floppy disk 238. Additionally, computer system 210 may be any kind of computing device, and so includes personal data assistants (PDAs), network appliance, X-window terminal or other such computing device. The operating system provided on computer system 210 may be MS-DOS®, MS-WINDOWS®, OS/2®, UNIX®, Linux® or other known operating system. Computer system 210 also 10 supports a number of Internet access tools, including, for example, an HTTP-compliant web browser having a JavaScript interpreter, such as Netscape Navigator® 3.0, Microsoft Explorer® 3.0 and the like.

Moreover, regarding the signals described herein, those skilled in the art will recognize that a signal may be directly transmitted from a first block to a second 15 block, or a signal may be modified (e.g., amplified, attenuated, delayed, latched, buffered, inverted, filtered or otherwise modified) between the blocks. Although the signals of the above described embodiment are characterized as transmitted from one block to the next, other embodiments of the present invention may include modified signals in place of such directly transmitted signals as long as the informational and/or 20 functional aspect of the signal is transmitted between blocks. To some extent, a signal input at a second block may be conceptualized as a second signal derived from a first signal output from a first block due to physical limitations of the circuitry involved (e.g., there will inevitably be some attenuation and delay). Therefore, as used herein, a second signal derived from a first signal includes the first signal or any 25 modifications to the first signal, whether due to circuit limitations or due to passage through other circuit elements which do not change the informational and/or final functional aspect of the first signal.

The foregoing described embodiment wherein the different components are contained within different other components (e.g., the various elements shown as 30 components of computer system 210). It is to be understood that such depicted

architectures are merely examples, and that in fact many other architectures can be implemented which achieve the same functionality. In an abstract, but still definite sense, any arrangement of components to achieve the same functionality is effectively "associated" such that the desired functionality is achieved. Hence, any two components herein combined to achieve a particular functionality can be seen as "associated with" each other such that the desired functionality is achieved, irrespective of architectures or intermediate components. Likewise, any two components so associated can also be viewed as being "operably connected", or "operably coupled", to each other to achieve the desired functionality.

10 Fig. 3 is a block diagram depicting a network 300 in which computer system 210 is coupled to an internetwork 310, which is coupled, in turn, to client systems 320 and 330, as well as a server 340. Internetwork 310 (e.g., the Internet) is also capable of coupling client systems 320 and 330, and server 340 to one another. With reference to computer system 210, modem 247, network interface 248 or some other method can be used to provide connectivity from computer system 210 to internetwork 310. Computer system 210, client system 320 and client system 330 are able to access information on server 340 using, for example, a web browser (not shown). Such a web browser allows computer system 210, as well as client systems 320 and 330, to access data on server 340 representing the pages of a website hosted 15 on server 340. Protocols for exchanging data via the Internet are well known to those skilled in the art. Although Fig. 3 depicts the use of the Internet for exchanging data, the present invention is not limited to the Internet or any particular network-based 20 environment.

25 Referring to Figs. 1, 2 and 3, a browser running on computer system 210 employs a TCP/IP connection to pass a request to server 340, which can run an HTTP "service" (e.g., under the WINDOWS® operating system) or a "daemon" (e.g., under the UNIX® operating system), for example. Such a request can be processed, for example, by contacting an HTTP server employing a protocol that can be used to communicate between the HTTP server and the client computer. The HTTP server 30 then responds to the protocol, typically by sending a "web page" formatted as an

HTML file. The browser interprets the HTML file and may form a visual representation of the same using local resources (e.g., fonts and colors).

An Example Architecture for Estimation of Component Gating and Shortage Risk in Manufacturing Operations

5 Please refer to Appendix A, which is attached hereto and is incorporated herein by reference, in its entirety and for all purposes. Moreover, in addition to the description of the method of the present invention contained within Appendix A, further information is available in the patent applications now incorporated by reference herein: This invention is related to Provisional Application No. 60/213,189, 10 filed 6/21/2000, which is incorporated by reference herein. It is also related to U.S. Patent Application Nos. 09/412,560, filed 10/5/1999, and 09/491,461, filed 1/26/2000, both of which are incorporated by reference herein.

15 Various processes according to embodiments of the present invention are discussed herein. It is appreciated that operations discussed herein may consist of directly entered commands by a computer system user or by steps executed by application specific hardware modules, but the preferred embodiment includes steps executed by software modules. The functionality of steps referred to herein may correspond to the functionality of modules or portions of modules.

20 The operations referred to herein may be modules or portions of modules (e.g., software, firmware or hardware modules). For example, although the described embodiment includes software modules and/or includes manually entered user commands, the various example modules may be application specific hardware modules. The software modules discussed herein may include script, batch or other executable files, or combinations and/or portions of such files. The software modules 25 may include a computer program or subroutines thereof encoded on computer-readable media.

Additionally, those skilled in the art will recognize that the boundaries between modules are merely illustrative and alternative embodiments may merge modules or impose an alternative decomposition of functionality of modules. For

example, the modules discussed herein may be decomposed into submodules to be executed as multiple computer processes, and, optionally, on multiple computers. Moreover, alternative embodiments may combine multiple instances of a particular module or submodule. Furthermore, those skilled in the art will recognize that the 5 operations described in example embodiment are for illustration only. Operations may be combined or the functionality of the operations may be distributed in additional operations in accordance with the invention.

Alternatively, such actions may be embodied in the structure of circuitry that implements such functionality, such as the micro-code of a complex instruction set 10 computer (CISC), firmware programmed into programmable or erasable/programmable devices, the configuration of a field-programmable gate array (FPGA), the design of a gate array or full-custom application-specific integrated circuit (ASIC), or the like.

Each of the blocks of the flow diagram may be executed by a module (e.g., a 15 software module) or a portion of a module or a computer system user using, for example, a computer system such as the storage router previously mentioned, or a similar network element, as well as a computer system such as computer system 210. Thus, the above described method, the operations thereof and modules therefor may be executed on a computer system configured to execute the operations of the method 20 and/or may be executed from computer-readable media. The method may be embodied in a machine-readable and/or computer-readable medium for configuring a computer system to execute the method. Thus, the software modules may be stored within and/or transmitted to a computer system memory to configure the computer system to perform the functions of the module.

Such a computer system normally processes information according to a 25 program (a list of internally stored instructions such as a particular application program and/or an operating system) and produces resultant output information via I/O devices. A computer process typically includes an executing (running) program or portion of a program, current program values and state information, and the resources 30 used by the operating system to manage the execution of the process. A parent

process may spawn other, child processes to help perform the overall functionality of the parent process. Because the parent process specifically spawns the child processes to perform a portion of the overall functionality of the parent process, the functions performed by child processes (and grandchild processes, etc.) may sometimes be
5 described as being performed by the parent process.

Such a computer system typically includes multiple computer processes executing "concurrently." Often, a computer system includes a single processing unit which is capable of supporting many active processes alternately. Although multiple processes may appear to be executing concurrently, at any given point in time only
10 one process is actually executed by the single processing unit. By rapidly changing the process executing, a computer system gives the appearance of concurrent process execution. The ability of a computer system to multiplex the computer system's resources among multiple processes in various stages of execution is called multitasking. Systems with multiple processing units, which by definition can support
15 true concurrent processing, are called multiprocessing systems. Active processes are often referred to as executing concurrently when such processes are executed in a multitasking and/or a multiprocessing environment.

The software modules described herein may be received by such a computer system, for example, from computer readable media. The computer readable media
20 may be permanently, removably or remotely coupled to the computer system. The computer readable media may non-exclusively include, for example, any number of the following: magnetic storage media including disk and tape storage media. optical storage media such as compact disk media (e.g., CD-ROM, CD-R, etc.) and digital video disk storage media. nonvolatile memory storage memory including
25 semiconductor-based memory units such as FLASH memory, EEPROM, EPROM, ROM or application specific integrated circuits. volatile storage media including registers, buffers or caches, main memory, RAM, and the like. and data transmission media including computer network, point-to-point telecommunication, and carrier wave transmission media. In a UNIX-based embodiment, the software modules may
30 be embodied in a file which may be a device, a terminal, a local or remote file, a

socket, a network connection, a signal, or other expedient of communication or state change. Other new and various types of computer-readable media may be used to store and/or transmit the software modules discussed herein.

While particular embodiments of the present invention have been shown and described, it will be obvious to those skilled in the art that, based upon the teachings herein, changes and modifications may be made without departing from this invention and its broader aspects and, therefore, the appended claims are to encompass within their scope all such changes and modifications as are within the true spirit and scope of this invention. Furthermore, it is to be understood that the invention is solely defined by the appended claims.

PROVISIONAL DRAFT